

HEAT PUMPS IN GENERAL

Heat pumps employ a vapor compression refrigeration system, which "...is a repeating cycle, does not deplete the refrigerant (fluid circulated through the system) which quickly absorbs and rejects heat at different pressures and temperatures, transferring heat from one place to another and oscillating vapor (heat) to liquid (cool) and back."

The four elements:

- **Compressor** – refrigerant vapor compressed to create the pressure differential that facilitates the flow of refrigerant through the system.
- **Condenser** – compressed vapor is turned into liquid.
- **Metering device** – the high pressure and high temperature liquid flow is controlled into the evaporator at a pressure drop.
- **Evaporator** – absorbs heat. The refrigerant removes humidity from the air as it goes through the evaporator. The low pressure, low temperature vapor then returns to the compressor. In general, the evaporator works at a temperature below the dew-point temperature. This in theory causes moisture in the air – humidity – to condense out of the air.

Many heat pumps are able to provide both heating and cooling. The cooling mode is simply the above process, but in reverse.

Reference: *Heat Pumps* by Eugene Silberstein (2016)

GENERAL WOODEN ART AND ARTIFACT STORAGE RECOMMENDATIONS

Undamaged wood is a highly stable material. However like any material, its lifespan is decreased by unstable conditions. Wooden objects benefit from **proofed fluctuation**, an observed behavior within an object that has equilibrated to a specific environment. This object will expand and contract throughout the year within its "proofed" natural conditions. Cracking that forms from this movement will typically not worsen year to year, but stay relatively consistent in size. While proofed fluctuation seems to protect the object from further mechanical damage, this can only be relied upon until the point of fatigue which is variable for each object, its age, and history. Chemical degradation and biological attack do not have a range of proofing; once these processes start, they are continuous until intervention. Additionally, paints and coatings on wooden objects do not benefit from proofed fluctuation and the mechanical and chemical degradation of these materials are compounded.

For collections storage, the objects should be protected from major fluctuations in both temperature and moisture content. Temperatures at or below 65°F and relative humidity of 50% is an ideal and typically attainable combination. When designing a storage space, it is important that this space is outfitted for its purpose, is sustainable regarding energy consumption and budget, and maintainable by staff or local contractor.

For objects within an open storage environment (sheds, historic homes, etc.), the main concern is decreasing humidity and dampness from the space to prevent both mechanical and biological risks. Realistically, this means maintaining a relative humidity (RH) at or below 75% year round. Noting that a consistent RH of 65%+ can lead to mold germination and growth within days. The chemical degradation risk temperature is 68°F, the rate of degradation doubles with each 9° increase. Cooler temperatures in the winter can significantly extend the lives of objects. However in order to prevent shocking the objects, the temperature shift from winter to summer needs to be gradual. Painted or coated wood seems to benefit from a protective polyethylene wrap or barrier.

Reference: ASHRAE Chapter 24: Museums, Galleries, Archives, and Libraries (2019)

“For the majority of cultural materials, a set point in the range of 44-45% relative humidity with an allowable drift of +/-5%, yielding a total annual range of 40% minimum to 60% maximum and a temperature range of 59-77°F is acceptable. Fluctuations must be minimized.”

Reference: “Crack Warp Shrink Flake” by Pamela Hatchfield (2011)

Let’s make sure we understand what’s going on with the relationship of temperature and moisture:

The relationship between temperature, moisture content, and relative humidity is shown in figure.1:

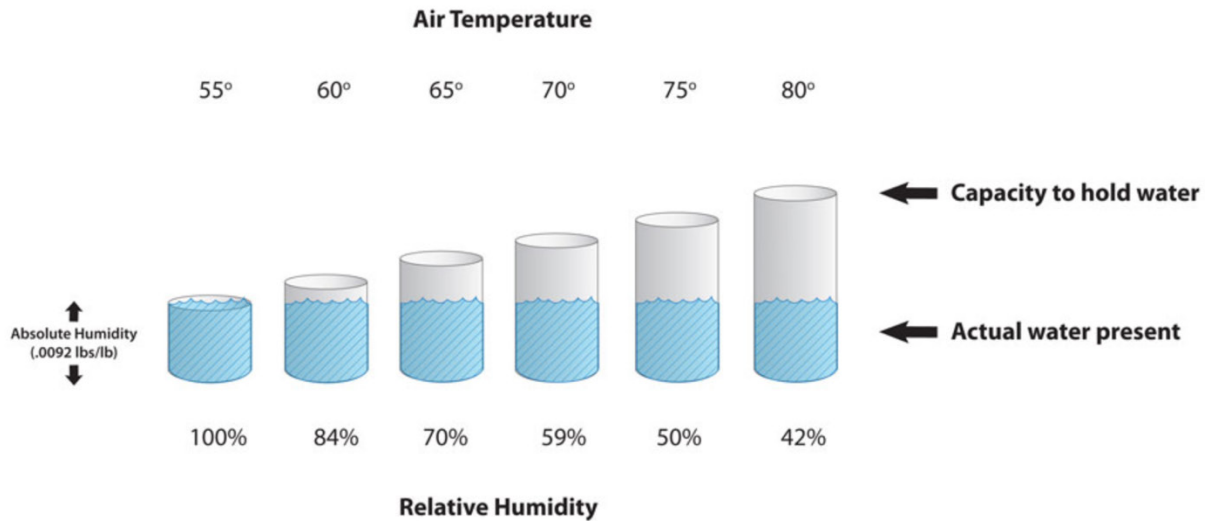


Figure 1: Temperature, Relative Humidity, and Dew Point from Image Permanence Institute
https://www.eclimatenotebook.com/fundamentals_nl.php

Dew point (DP) and temperature (T) are measurable. Relative humidity (RH) is a calculated value from this data. Dew point is a measure of how much water vapor the air can hold at a given temperature. At lower temperatures, the air cannot hold as much, which is why we see condensation on cold surfaces. Higher temperatures can hold more moisture in the air without condensing. While warmer temperatures seem like a solution to humidity, this is an incomplete way of looking at the way humidity affects objects.

As seen in fig. 1, the same amount of moisture is in the air, regardless of temperature. The relative humidity is an indication of how the space feels based on the change in temperature. Many spaces are designed around human comfort. Since higher temperature air can contain more moisture, and SE Alaska is in a temperate rainforest, simply heating the air makes it feel less humid and warmer. However, the overall moisture content in the air, or dew point, remains the same. Meaning that an object within these conditions will be conditioned to equilibrate at the dew point, or as referenced in fig. 1, the actual water present.

An example in the Southeast Alaska rainforest:

August 3, 2020 was 60°F with 93% relative humidity and a dew point of 58° in a storage shed for oversized collections mostly made of wood. Figure 2 shows how these conditions were experienced by the wood objects on the Dew Point Calculator from the Image Permanence Institute.

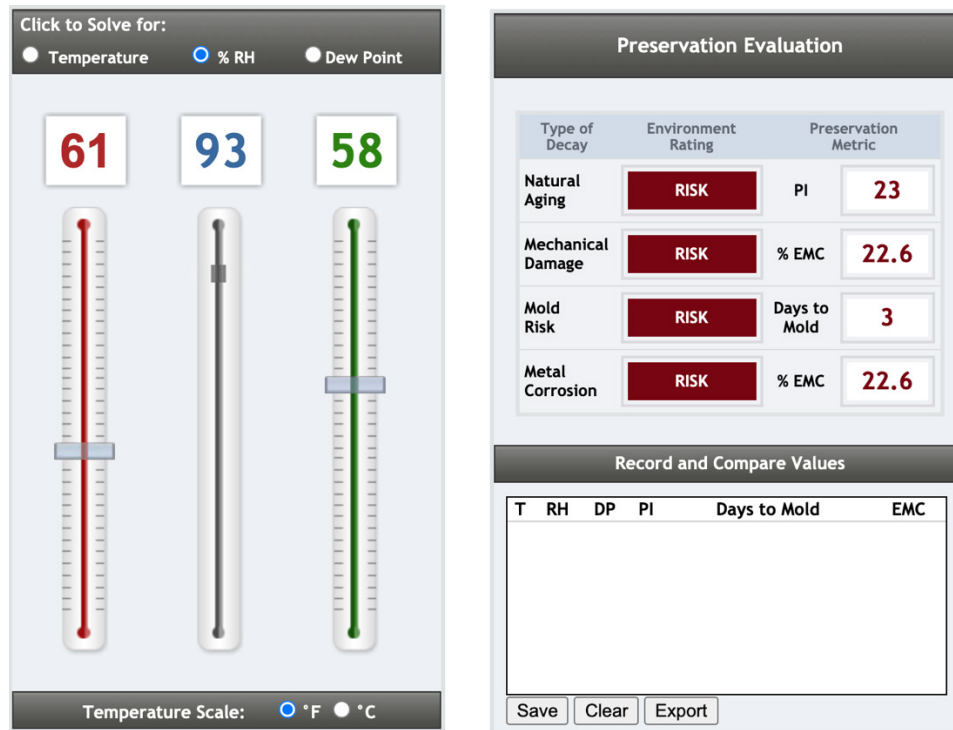


Figure 2: August 3, 2020 weather conditions in Southeast Alaska.
<http://www.dpcalc.org>

On the left we have the T, RH, and DP values, on the right is how these specific values impact cultural heritage objects. The Natural Aging Preservation Index (PI) is a calculated rate of chemical decay over a number of years. The Mechanical Damage percentage to Equilibrium Moisture Content (EMC) measures the amount of moisture hygroscopic objects absorb and the level of risk that carries. The general Mold Risk is determined based on typical conditions and rates for germination. Finally Metal Corrosion uses the EMC data specifically to calculate how metals will react to this environment. The climate poses a risk to the wood mechanically (the wood expands and contracts with fluctuating moisture), chemically (high heat and moisture level accelerate aging and rotting of wood), and biologically (the risk of mold is high). Corrosion risk is also high.

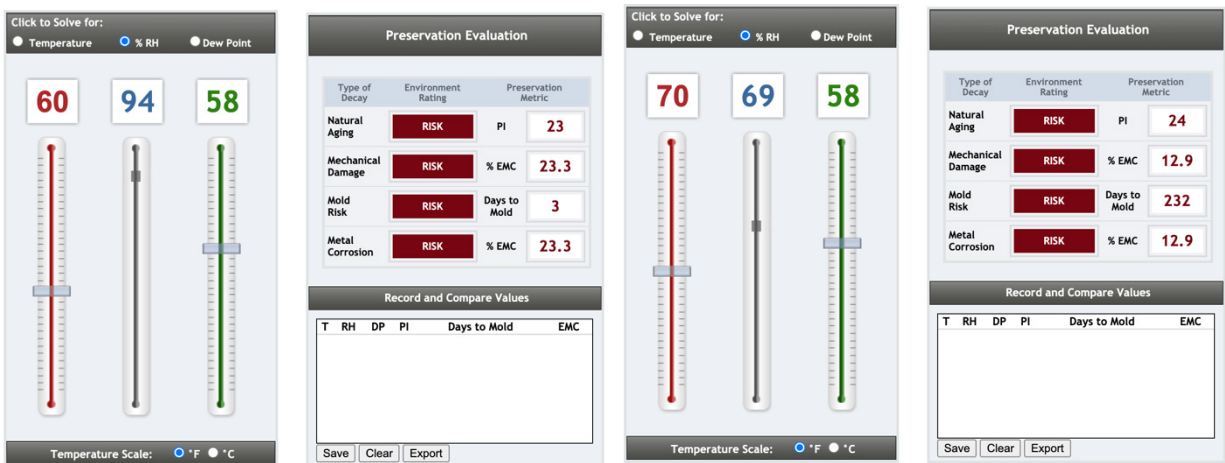


Figure 3: Climate data for CJS after installation of two heat pumps in May 2019; data averaged from May-October 2019, ranging from low temperature (left) to high temperature (right).

The important takeaway from this data is that without a properly insulated building, the outdoor conditions are the same as the indoor conditions. Without dehumidification in place, the dew point of the interior will remain at 58° even if the relative humidity drops with the rise in temperature. The moisture content of the interior air remains the same indoors as outdoors without dehumidification; it just feels less humid. Inside the shed, the temperature and relative humidity data have been recorded and figure 3 illustrates the low and high temperature range from this data while the heat pumps were running (data is from May – October 2019).

In the range of temperatures attainable with the heat pumps (60-70°F) and the somewhat lowered RH (69-94%), the environment still holds too much moisture. The collections stored in the shed remain at significant risk.

Now, you may look at the data on the right in fig. 3 and think that the mold risk isn't bad – it's 232 days until you have a problem, and by then, we'll be in winter with lower temperatures, so that's ok, right? **Wrong.** While mold doesn't germinate and spread well in cooler winter temperatures, that moisture content is still present in the wooden object meaning that (a) the moment spring temperatures rise, you have a mold risk, and (b) the hygroscopic wood is equilibrated at a high moisture content which is dangerous for the risk of mechanical and chemical damage. The object must be sustained at a moisture equilibrium below the mold risk line of 70%. This is simply not possible without lowering the dew point. By dehumidifying the space and sealing the indoor environment, the dew point for the indoor space can be lowered consistently and efficiently.

The edge of OK preservation conditions (highest possible acceptable dew point, meaning least possible dehumidification) to accommodate wooden artifacts is shown in figure. 4. In order to

reach this point, dehumidification must be employed to lower the dew point. Only then will true dehumidification of the collection be achieved to insure its preservation.

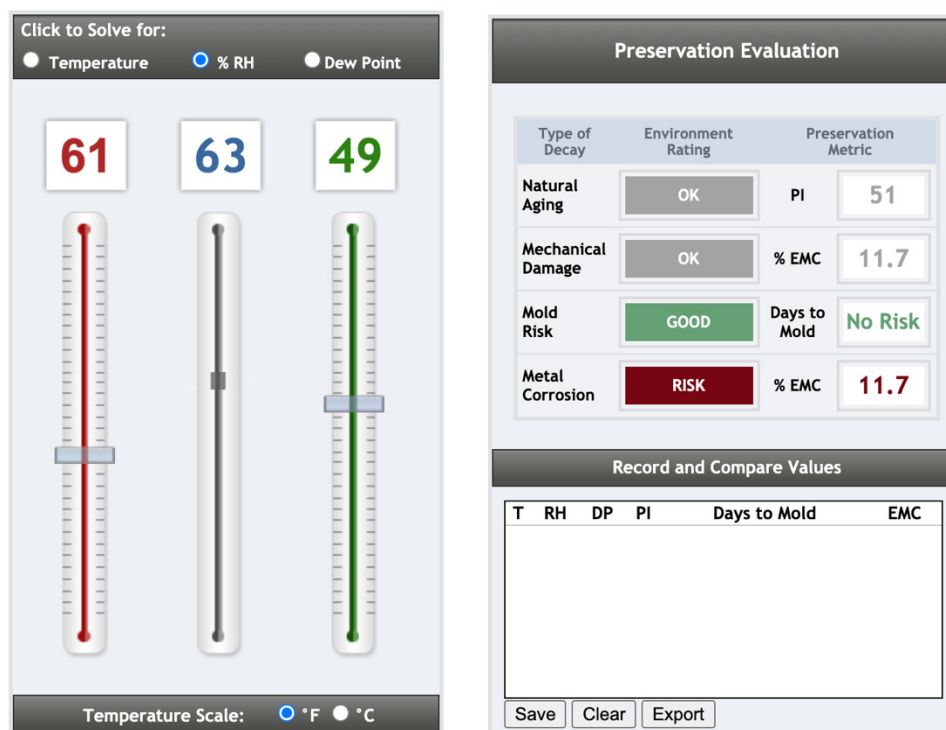


Figure 4: Acceptable levels for storage of wooden artifacts.

References:

- Image Permanence Institute's Dew Point Calculator: <http://www.dpalc.org/>
- More information on dew point: https://www.eclimatenotebook.com/fundamentals_nl.php
- This video from the National Weather Service in Chicago explains the relationship between temperature, dewpoint, and relative humidity well in a weather sense: <https://www.youtube.com/watch?v=OiejHVHrdOo>

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